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REAL-TIME RADIOGRAPHY
INSPECTION OF ARAMID (KEVLAR)
COMPOSITE PASGT HELMETS
FEASIBILITY STUDY

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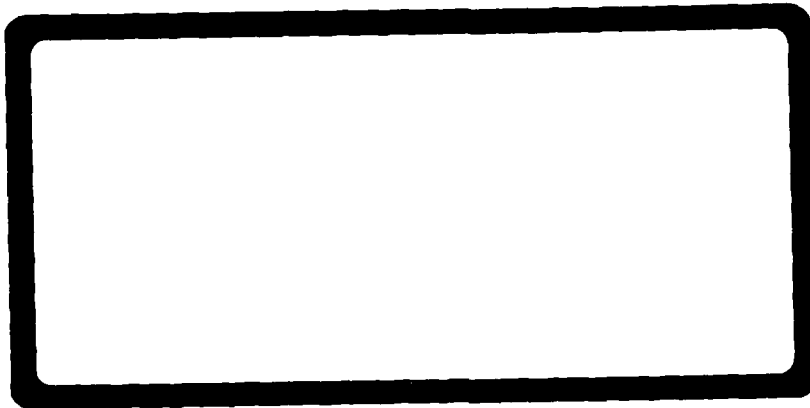
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Study conducted to determine feasibility of using real time radiography nondestructive testing of compression molded aramid (Kevlar) composite helmets. Results indicated a practical capability to inspect for defects and number of layers of aramid in the helmet.

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TR 86-2

REAL-TIME RADIOGRAPHY INSPECTION
OF ARAMID (KEVLAR) COMPOSITE
PASGT HELMETS
FEASIBILITY STUDY

UNITED STATES DEFENSE LOGISTICS AGENCY
DEFENSE ELECTRONICS SUPPLY CENTER
DAYTON, OHIO
CONTRACT NO. DLA900-86-M-Z929
JUNE 16, 1986

Written by

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Sales Manager - Digital Systems

AUTOMATION/SPERRY, a unit of Qualcorp
Chatsworth, California
U.S.A.

1986

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1.0 INTRODUCTION

This study was conducted to determine the feasibility of using real-time radiography inspection on compression molded aramid (Kevlar) Paratrooper and Support Ground Troop (PASGT) helmets. The present destructive testing method (ballistic) has been determined to be inadequate and costly.

In order to determine the feasibility of using Realtime Radiography inspection of these PASGT helmets, (6) sample helmet shells with internal, artificially manufactured defects were provided to Automation/Sperry by the Defense Logistics Agency. Upon completion of the Ultrasonic Feasibility study (TR 86-1), the test samples were forwarded to Lockheed-Sunnyvale Ca. for evaluation.

The objective of this evaluation was to qualify the Material Density variations due to "Pin wheel" Kevlar lay-up, wrinkles, resin flow, and reinforce previous test data gathered during the Ultrasonic feasibilty study. Computerized digital imaging techniques were used by Lockheed to enhance the data for ease of interpretation.

2.0 SUMMARY OF RESULTS

The (6) PASGT helmet samples and 7 thickness samples were evaluated by Lockheed using the HERTIS Real-Time Radiograph system. Xerographic type plots of the CRT image are presented in the test data section of this report. A Video tape of several helmet samples being examined was also made available for better interpretation of the test results.

Angular positioning (tangtial) of the helmet samples with respect to the x-ray source yielded images of the wrinkled layers, variation in resin flow, and unknown anomalies. In addition, the artificial defects are clearly visible in the non-enhanced images.

3.0 CONCLUSIONS

Real-Time Radiography can be applied to the inspection of the PASGT helmets. The ability to detect differences in the Kevlar lay-up and the number of layers is more readily adaptable to Radiography inspection than Ultrasonics. Although, Ultrasonic inspection would be more sensitive to the detection of internal discontinuities such as, delaminations and blisters. Both techniques would be complementary to one another.

4.0 EQUIPMENT

HERTIS - High-Energy-Real-Time Inspection system consisting of the following major assemblies and as shown in figure 1.

- Camera - made up of high sensitivity and high resolution X-Ray screens, and advanced low-high-level television (LLTV)

- Image Processor - Programmable, 4 channel digital processor

- Control Console - T.V. monitor for real time imaging, manual or automatic scanning spatial coordinate readout, and audio and video tape recoder.

- X-Ray Machine - 60 K.V., 20 ma Seifert unit.

5.0 TEST PROCEDURE

Seven samples of similar construction as the helmets were submitted along with the helmet crowns. Each one was missing one more ply than the preceding one starting with the thickest one. They are numbered 14 through 20. These were tested to assure that the relative density was the same for all them. Thickness measurements were made on each one and charted on one axis of graph #1.

Brightness readings were then made of the sample in the Hertis system. These were plotted on the other axes of graph 1.

The graph shows the change in brightness as a function of thickness. Brightness change is a relative measure of density and/or thickness variation.

All the samples except #17 fit along the smooth curve plotted in graph 1. Sample #17 had not been submitted to a density check at the time it was X-rayed and a brightness measurement made. Since the density check involved immersing the samples in water, and #17 was not, it is believed that is the reason the brightness reading does not fall along the curve.

This procedure established a direct correlation between missing plys and brightness readings.

The crown sections all of helmet's #1, #2, #3 and #6 were then placed in the HERTIS system as shown in Figure 2. These were articulated while positioned between the X-Ray machine and the radiographic screen and exposed up to 25K VP at 20 ma radiation.

The resultant image on the screen was scanned with the tv
camera and digitized to a 8 bit resolution in the image
processor. Via the image processor it was then possible to
enhance the total image, or selected regions of the images
and present these on a monitor for evaluation.

Recordings off the monitors were than made for the crown
sections. These are numbered 1 through 11 inclusive. Two
perspectives of the helmet crown are shown, a radial view of
the surface for helmet section 1, 2 and 3 and radial and
tangential views of helmet section #6. Views #1, #2, #4, #7
and #8 are integrated images showing the fine detail possible
with the system. Views #3, #5 and #6 are non-enhanced images
and represent a "normal" view. Viewers #9 and #11 are
subtracted images that enhance certain characteristics in the
helmet crossections.

With the exception of view #1 the missing ply section is
clearly discernable in all views. In addition wrinkles,
corrugations and fiber orientation are readily visible in
many views. View #8 is an expanded section of view #9
showing certain artifacts believed to be natural flaws
occurring in the area of the missing ply sections.

Views of samples #14 and #20 are also shown with a density
histogram taken in the same area on each sample. The
difference in brightness/density between samples is readily
apparent and can be read out with an accuracy of 1 part/256.

A real time video tape with audio of Helmet section #6 was
made and accompanies this report.

6.0 TEST RESULTS

All the artificially produced flaws, i.e. the missing ply,
were easily detected when viewed tangentially or radially.
Paradoxically the areas where the ply was missing showed up
as a more dense area than the area surrounding it. It is
believed that resin flowed to fill the void created by the
missing section of ply and created an area of greater density
than elsewhere.

In all the helmet samples there were localized areas whose
brightness was about equal to the brightness of the area
where the ply was cut out.

7.0 CONCLUSIONS

The accompanying video tape and images conclusively show that using low energy, high current X-Ray with the HERTIS imaging system it is possible to detect thickness/density differences caused by as little as a single ply. The process is fast and shows promise of being automated for high through put rates. The limited scope of this application study did not provide the time and effort required to quantify the differences between areas of different densities. The HERTIS system is capable of making such comparisons to allow decision making based upon present accept/reject criteria. A more complete study based upon full sized samples and control standards would be able to demonstrate this capability.

RECOMMENDATIONS

Further Radiographic examinations of the PASGT helmets should be conducted to qualify using the Real-Time Radiographic method of NDT for production inspection. Reference standards with artificial defects of various known sizes and types must be examined to determine the minimum size defect that can be detected within a (19) layer kevlar structure.

Since a complete missing layer (ply) does not provide an easily identifiable area as a cut out does, it is recommended that on new production runs each layer have a cut out in a different area of the "pin wheel". This technique would permit counting the number of cut outs to determine the number of layers used.

Based on the results of this preliminary study we strongly believe it is possible to determine whether layers are missing on PASGT helmets. It is clear other flaws such as areas of porosity can be detected.

We recommend that a more comprehensive study be undertaken with Lockheeds NDT Technology Laboratory to determine the specific technique and applicable software programs that need to be designed for production testing of helmets.

8.0 TEST DATA

DATA REDUCTION FORM

*   PASGT HELMET SHELL SAMPLES
    (19) LAYERS OF ARAMID (KEVLAR)

NOTE: ALL SAMPLES (EXCEPT # 1) HAD ARTIFICIAL DEFECTS
FABRICATED INTO THE CENTER OF THE CROWN (TOP) OF THE SHELL
SAMPLE. THESE DEFECTS WERE CREATED BY CUTTING A 1.0" SQUARE
FROM THE LAYER(S) PRIOR TO BONDING. EACH OF THE (19) LAYERS
ARE IDENTIFIED AS 1 THROUGH 19 WITH LAYER 1 ON THE INSIDE
(DATE CODE SIDE) OF THE SAMPLE. IN ADDITION TO THE
MANUFACTURED DEFECTS A .250" x 1.0" FOAM TAPE STRIP WAS
AFFIXED TO THE INSIDE OF THE HELMET NEXT TO THE CODE FOR PLOT
ORIENTATION PURPOSES.

SAMPLE NO.	DEFECT PLACEMENT LAYER(S)	ATTENUATION RANGE
1	NONE	
2	3	
3	3,5	
4	3,5,7	
5	3,5,7,9	
6	5,7,9,11,13	

A UNIT OF QUALCORP

ULTRASONIC TEST STUDY OF ARAMID
(KEVLAR) COMPOSITE SAMPLES
FOR
DEFENSE ELECTRONICS SUPPLY CENTER
DAYTON, OHIO

SEPTEMBER 1986

Automation/Sperry
A Unit of Qualcorp
20327 Nordhoff Street
Chatsworth, CA   91311

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Sample No.1
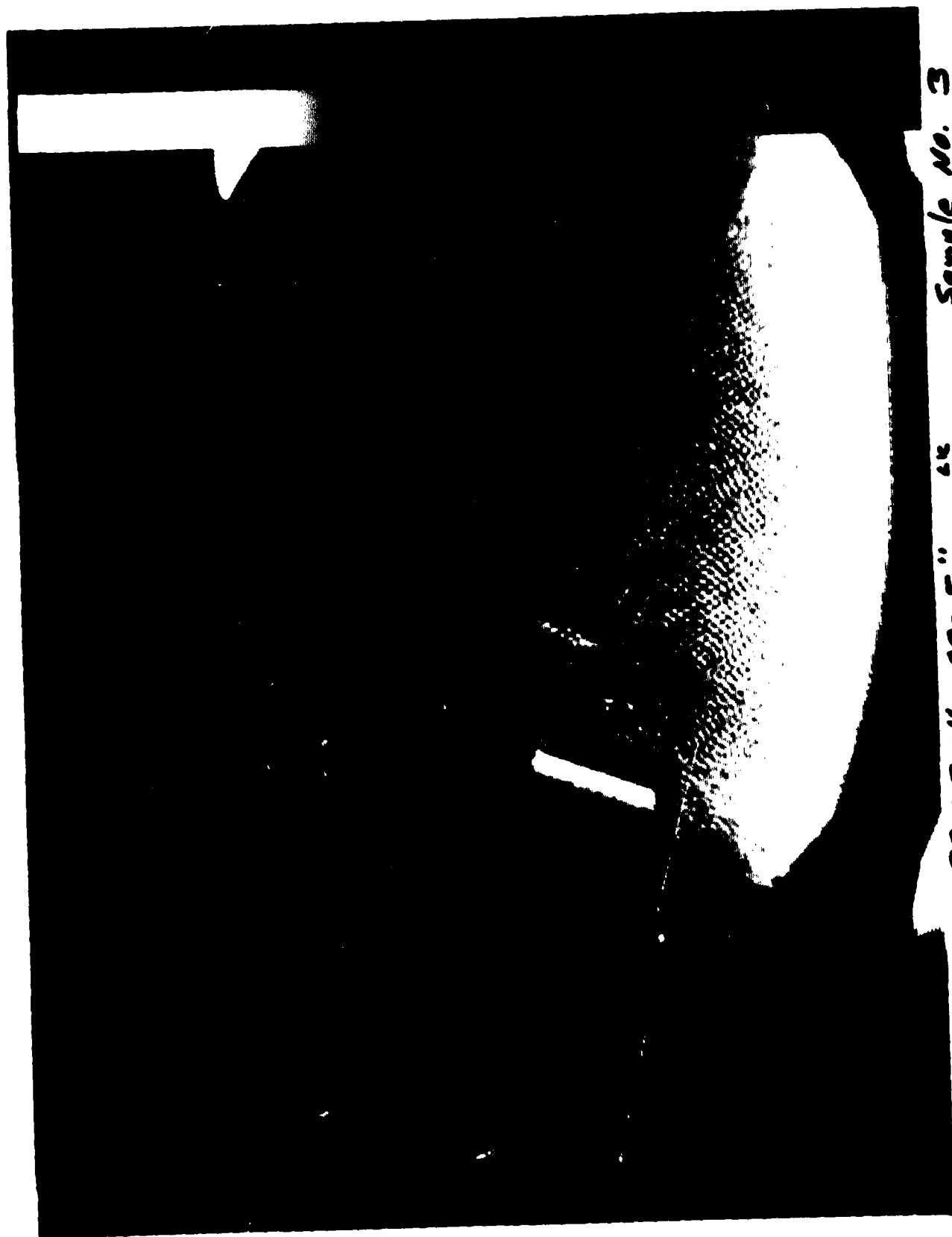
SR.
8.4.9

FS:34" 0525"

25KVP 20μA NNP2

25KV 20mA FS=34" OS=5" 6.4.8t Sample No. 3

HELMET 2

normal

25KV 20mA FS:24" OS:6" 6-4-86 Sample 2

④
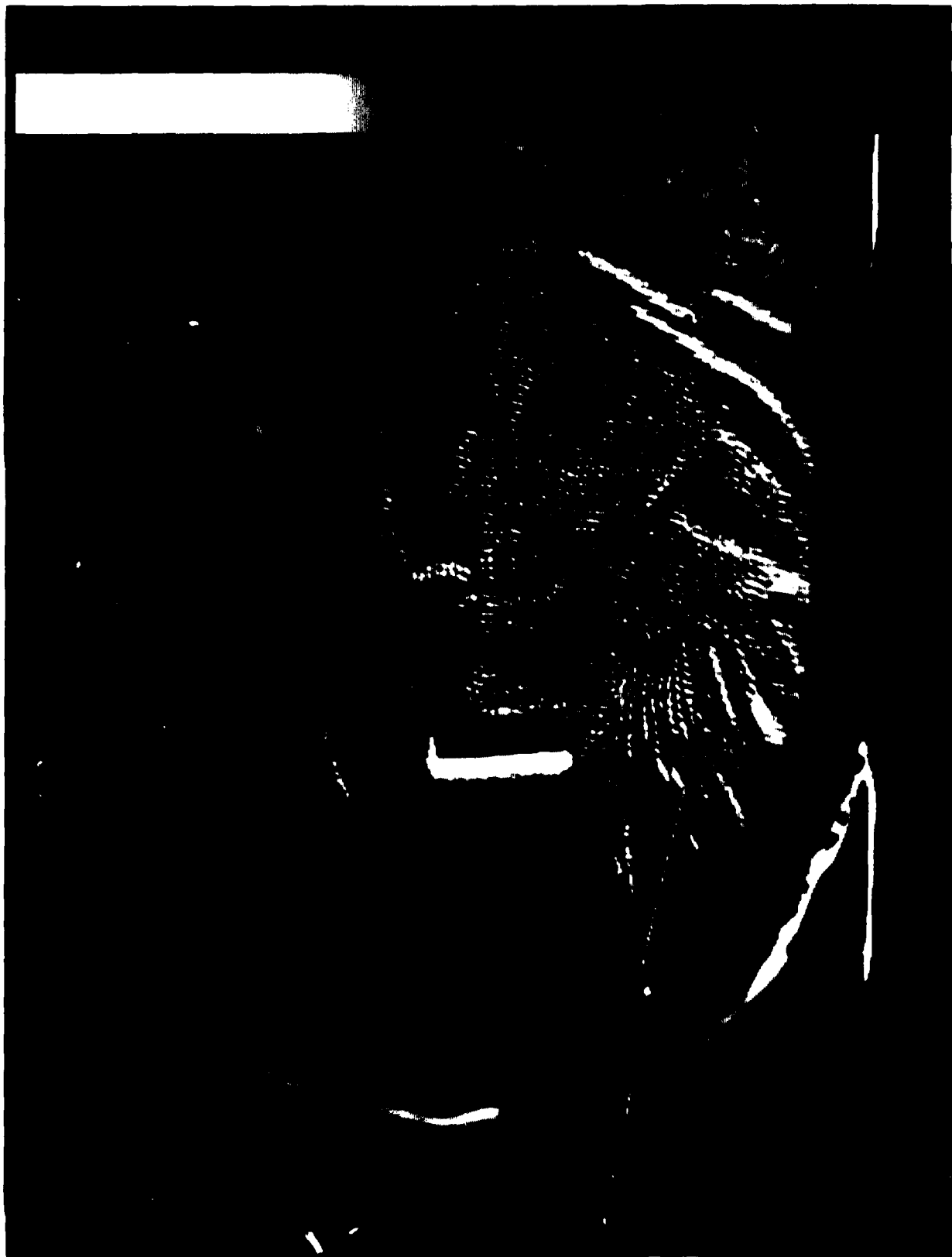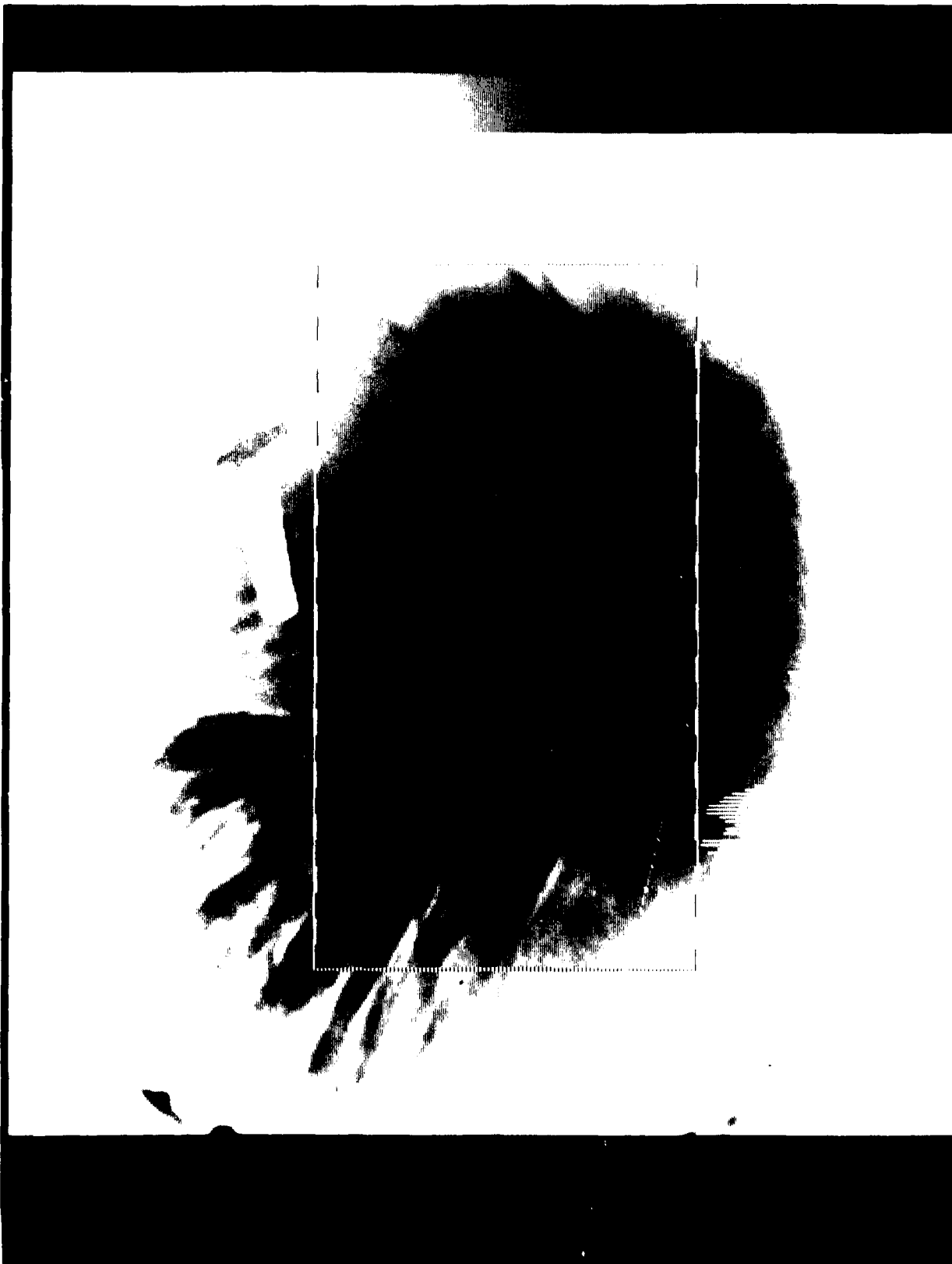
HELMET 2

NORMAL

20 kVp 20mm
rS 18" OSV"
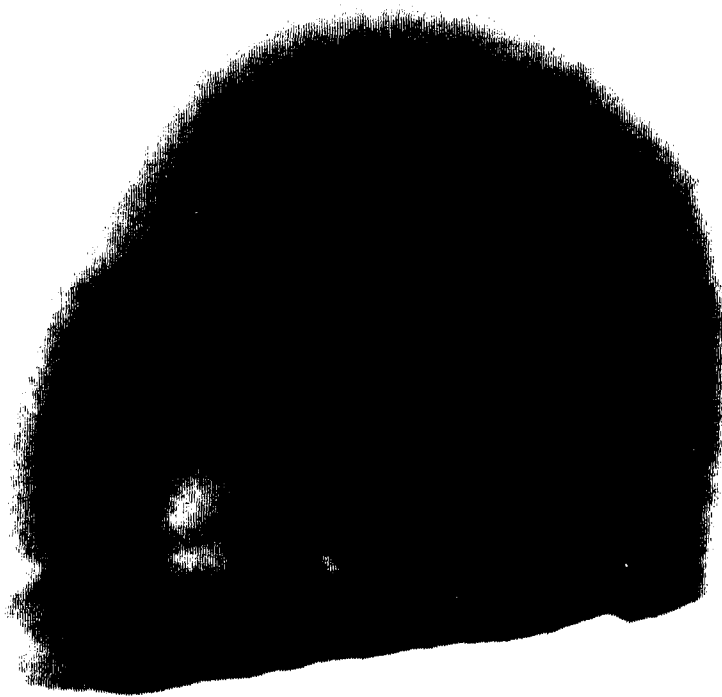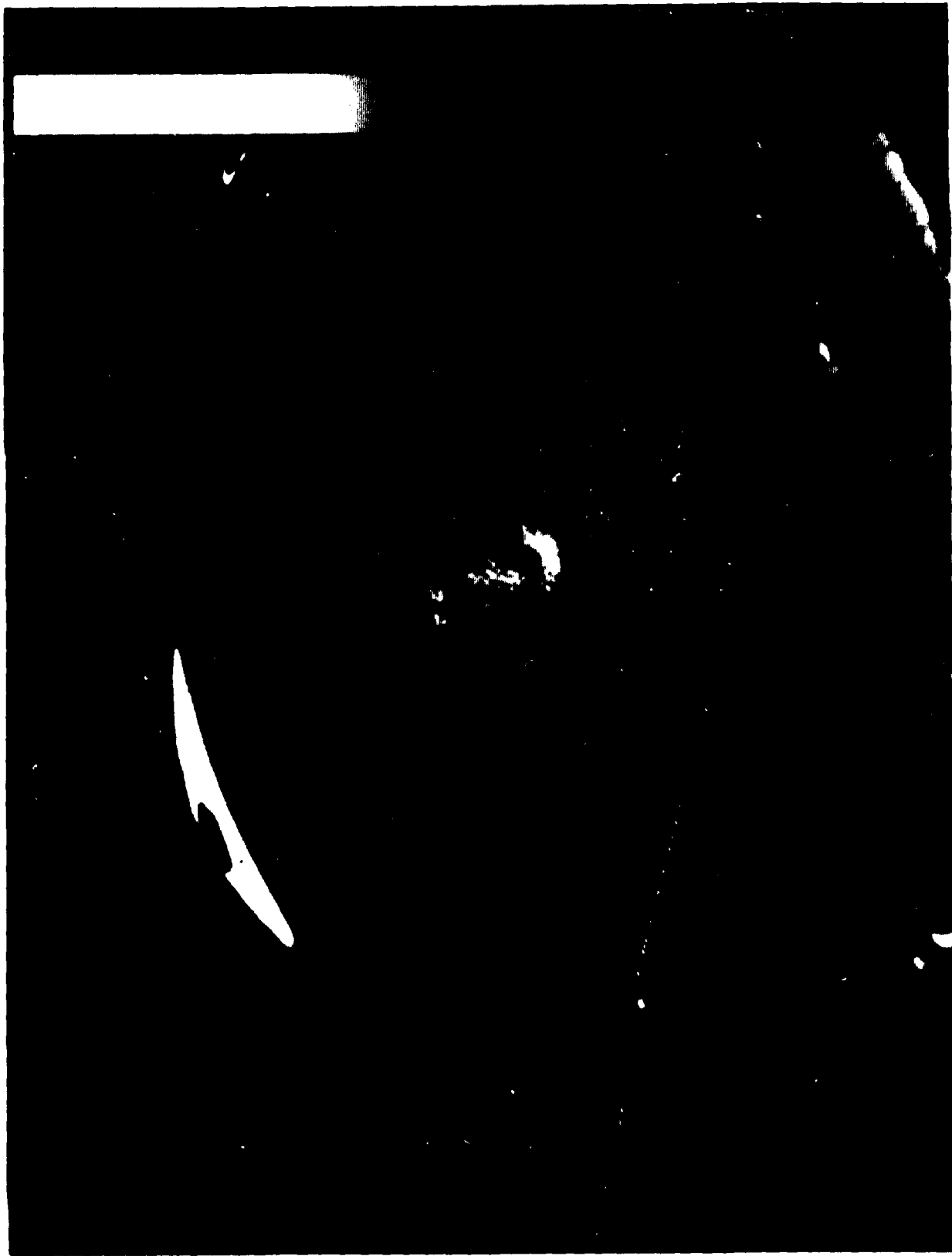
HELMET 6

25 KVP 24MM FS=94 05:5" 6K 6.4.96 Sample No. 6

TANGENT MAG   HELMET 6

TANGENT   HELMET 6

TANGENT

HELMET 6

9-11-9

9000 2000
PSI 12.5°
50 1°
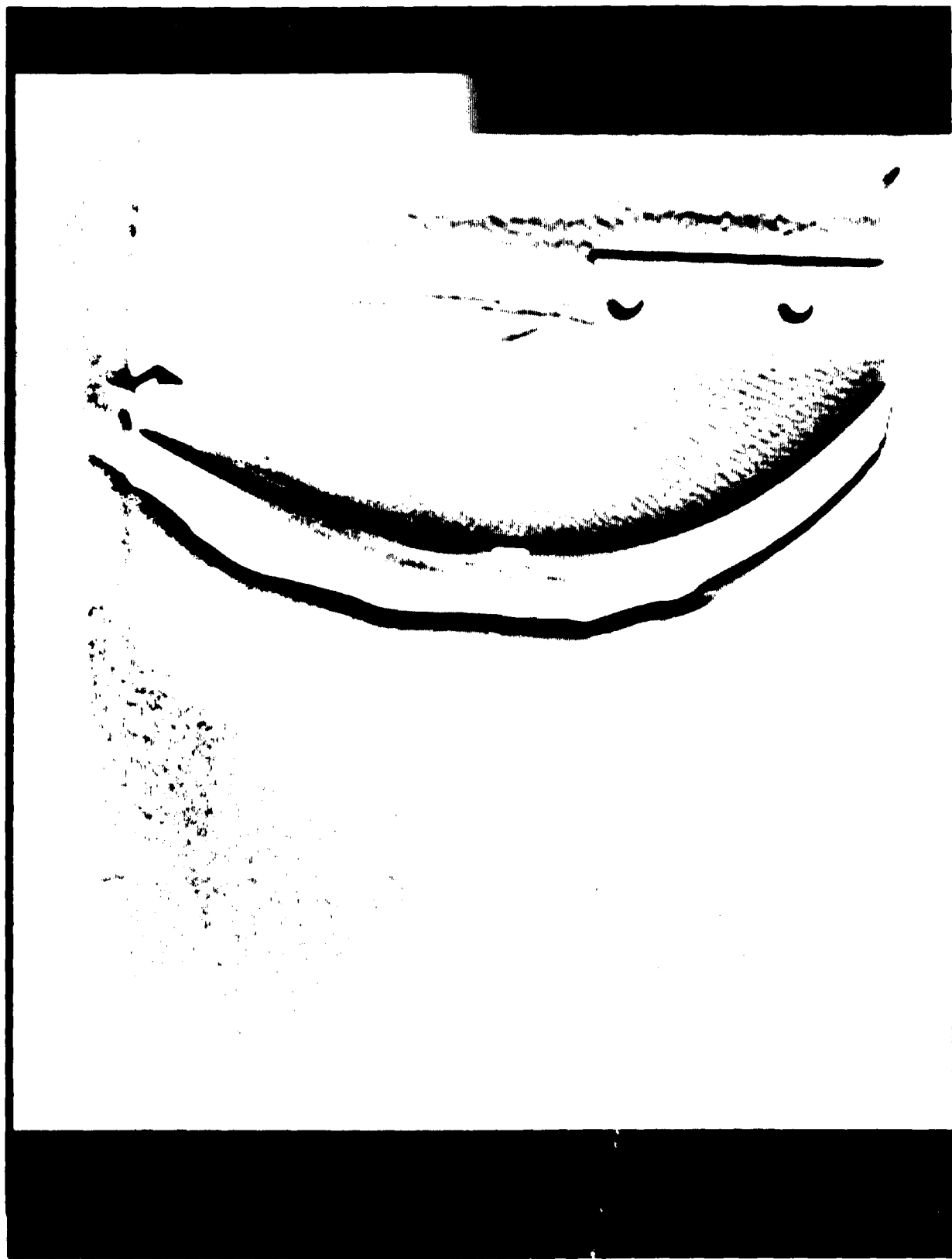
TANGOUT REAL TIME HELMET 6
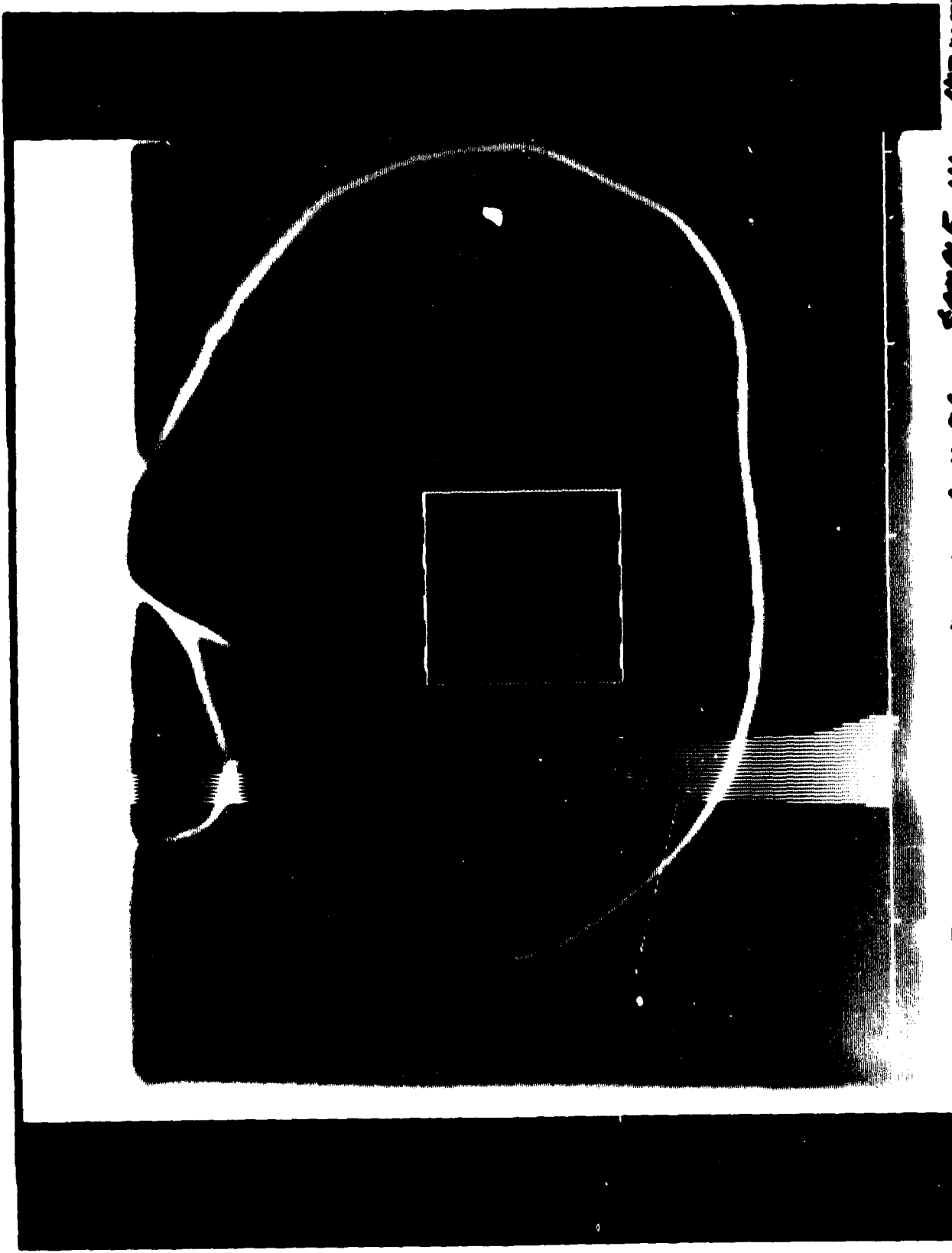
20 KVP 20MA FS 18" OSV" CK 6-11-86 SAMPLE 14 HELMET
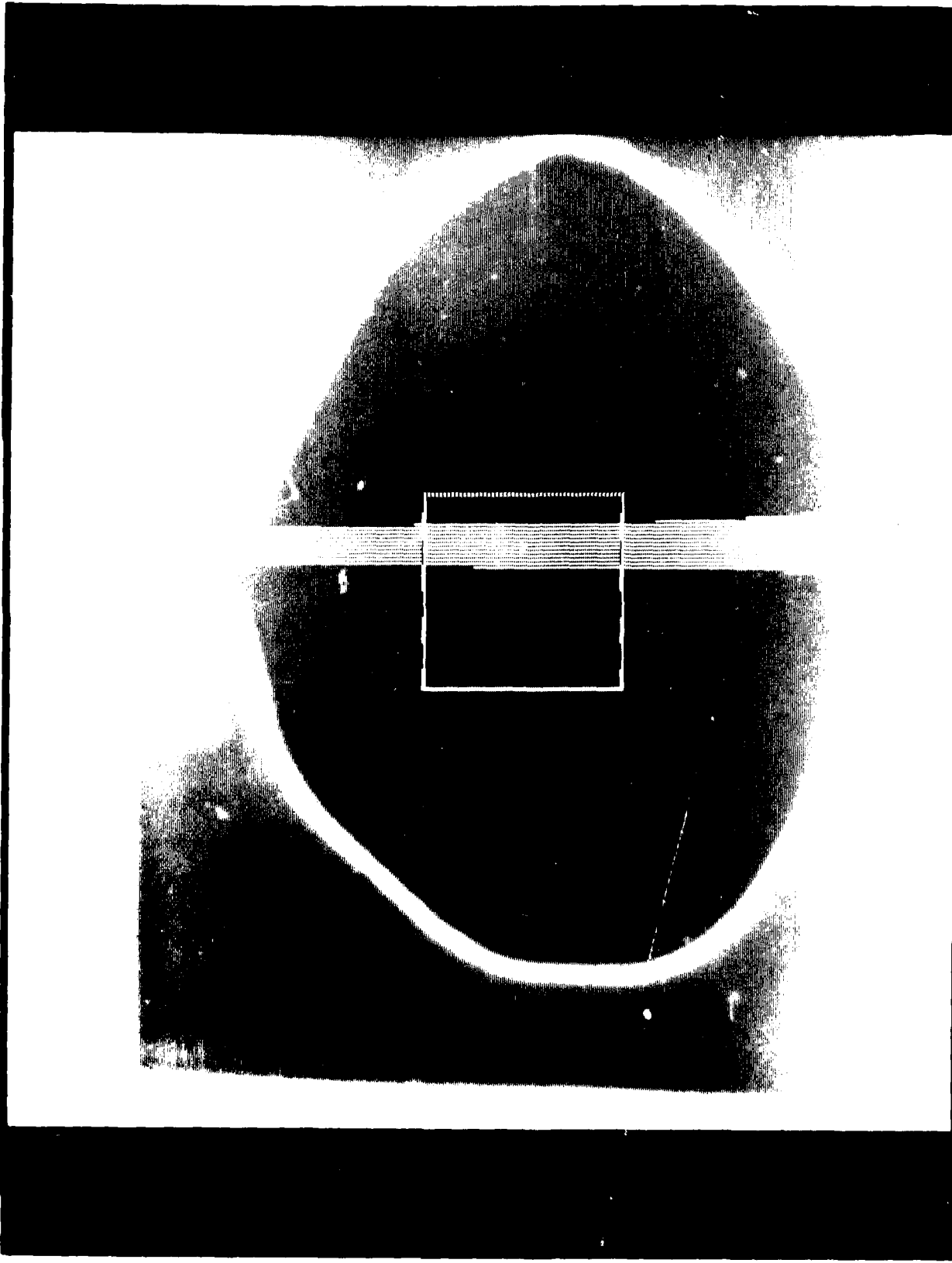
(12)

20 KVP 20MM PS 18" OS 4" CR 6-11-86 Sample 20 HELMET
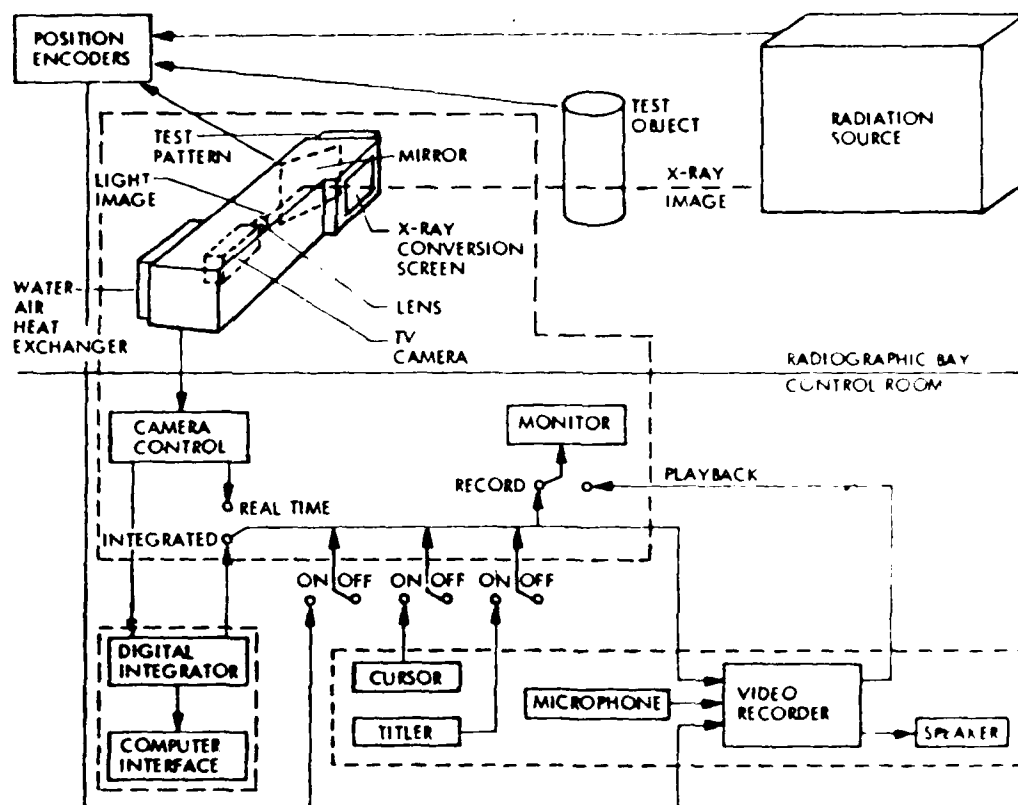
FIG. 1—*Block diagram of real-time radiographic system.*

HELMET
CROWN

HIGH SENSITIVITY,
HIGH RESOLUTION
SCREEN

X-RAY
SOURCE

PART ARTICULATOR

TV CAMERA

FIGURE 2

GRAPH L

HELMET TEST   6-11-86   LR

20 KVP , 20 MA , FS 18 , 05 4 , @H , I₀-026

WHITE
=LEAD

BLACK
= AIR

BRIGHTNESS (0-255)

THICKNESS (INCH)

SAMPLE 14 —
T=.248" ρ=1.26   n=52

SAMPLE 15 —
T=.265" ρ=1.28   n=4

SAMPLE 16 —
T=.279" ρ=1.27   n=6

SAMPLE 17 —
T=.286   ρ=1.27   n=6

SAMPLE 18 —
T=.313" ρ=1.26   n=4

SAMPLE 19 —
T=.329" ρ=1.26   n=3

SAMPLE 20—
T=.341" ρ=1.28   n=16